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(54) Intraocular optical system.

(57) The invention relates to an intraocular optical system (7) for insertion into the capsula lentis after removal of the natural eye lens, which is characterized in that it is a hollow body having an outer shape following the inner shape of the capsula lentis (6) at least in the main lines and leaning against its inner wall and keeping it in a moderately tensioned state, and comprises a front element (1), a rear element (2), an elastically deformable element (3) provided between the front element (1) and the rear element (2), and one to four lenses (4, 5) at least one of the lenses (4, 5) being provided such as to move axially at contraction and release of the accommodation muscles of the eye.

This intraocular optical system is preferably made from biocompatible materials. The system (7) deformed into a rod-like form with a diameter of less than 3 mm can be introduced into the eye through a very small incision. The system does not induce tissu irritation effects or secondary glaucoma and is self-accomodating.

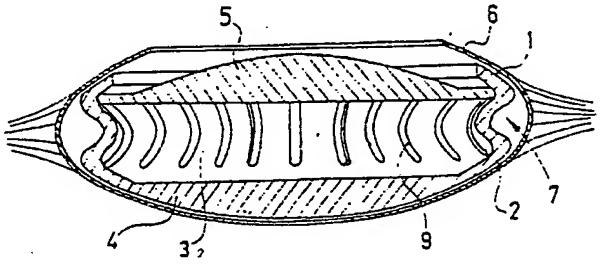

FIG.1

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Intraocular optical system

The invention pertains to an intraocular optical lens system for insertion into the capsula lentis after removal of the natural eye lens.

Intraocular lenses, above all hard lenses made from poly(methyl methacrylate), which are inserted into the capsula lentis after removal of the natural lens, usually as a consequence of cataract, reached a considerable perfection but still have some shortcomings. Some of them, for example, the tendency to the growth of cells on the surface of the lenses and irritation of living tissues, predominantly in the places of the contact of supporting projections (haptics), and the tendeny to form strong light reflexes, could be overcome by a surface hydrophilization by forming a soft surface layer having a swelling gradient, but the shortcoming of the necessity to make a long incision at operation still remains unsolved.

A considerable improvement could be achieved by soft intraocular lenses based on hydrophilic gels (US patent application ser. no. 134 222) which can be inserted in a suitably deformed state into the preserved capsula lentis through a small incision, where the lens then assumes its final, correct shape and required position.

A disadvantage of soft intraocular lenses based on hydrophilic gels used so far in comparison with the original natural lens consists in the difficult accommodation to various distances, especially in elderly patients. This is due to the fact that hydrogels need a larger power for deformation than can be developed by the pertinent eye muscles. On the other hand, very soft lenses have only a low refractive index of light and low strength, and a large volume, which may develop the so-called secondary glaucoma due to clogging of the natural passages.

It is the object of the present invention to provide an intraocular optical lens system for insertion into the eye after removal of the natural lens which is not subject to the shortcomings of prior art intraocular lenses, particularly irritation of adjacent tissues, can be introduced into the eye through a small incision, fits into the original capsula lentis and allows accommodation.

The above object is achieved according to the claims. The dependent claims relate to preferred embodiments.

The intraocular optical system according to the invention for insertion into the capsula lentis after removal of the natural eye lens is characterized in that it

(A) is a hollow body having an outer shape following the inner shape of the capsula lentis at least in the main lines and leaning against the inner wall of the capsula lentis and keeping it in a moderately tensioned state,
and

(B) comprises
- a front element,
- a rear element,
- an elastically deformable element provided between the front element and the rear element,
and
- one to four lenses arranged such as to be placed in the main axis of the eye, at least one of the lenses being provided such as to move axially at contraction and release of the accommodation muscles of the eye and thus to change its position between the retina and the cornea.

The elastically deformable element has preferably elasticity in the direction of the optical or geometrical axis of the system.

The intraocular optical system according to the present invention is preferably made partially or in its entirety from a homopolymer or a copolymer on the basis of acrylates, methacrylates and/or hydroxyalkyl acrylates and/or hydroxyalkyl methacrylates, such as hydroxyethyl methacrylate (HEMA).

At least one of the lenses may be placed in the optical system concerned outside the geometric center of the system and of the capsula lentis.

The intraocular optical system of the present invention is preferably made partially or in its entirety from a biocompatible material, for example, from silicon elastomers, hydrogels, and the like, which are advantageously elastic and have a shape memory, for example, partially dried hydrogels, and which may be hydrophilized at the surface.

The intraocular optical system can be inserted into the eye through a small incision, i.e. smaller than 3 mm, in a deformed state, which can be realized when it is made from a material having a glass-transition temperature T_g in the range of -5 to 45 °C, or from a material the T_g value of which can be adjusted before implantation in such a way that it meets the above condition, for example, by swelling a hydrophilic gel into a non-equilibrium state.

In this case, the system is heated above its glass-transition temperature, deformed into a rod-like shape with a diameter smaller than 3 mm, and cooled below this temperature while retaining its rod-like shape. After insertion into th eye, the system spreads into its original shape due to the body temperature or rehydration. The lenses of the optical system can be inserted into the eye in the same way.

The intraocular optical system according to the

invention allows to use lenses from an arbitrary material, i.e. not only from a hydrogel but also from hard acrylic polymers such as poly(methyl methacrylate), without the known shortcomings, particularly Irritation of adjacent tissues, becoming operative. On the contrary, the application of hard lenses with a high refractive index enables to reduce their dimension in such a way that the posterior chamber of the eye remains unfilled, and the whole system fits into the original capsula lentis from which the natural, turbid lens was removed, for example, by phaco-emulsification.

It is of advantage, if at least one of the lenses of the optical system is made of a synthetic polymer having a refractive index of light of at least 1.336.

The intraocular optical system may have the shape of ellipsoid of revolution provided on its circumference with an equatorial slot with a row of holes, and may be provided on its front side with an opening which has a smaller diameter than that of the opening in the capsula lentis.

The front part and the rear part of the system may be realized in the form of rings with a diameter < 9 mm or as parts of hollow bodies of revolution, such as a sphere, a paraboloid, an ellipsoid, and the like. The lenses (optical elements) may be integrated therewith, whereby the lenses and their case may form one single piece. The elastically deformable element may have the shape of fibers, strips, a spiral, or a corrugated body.

One single lens may be provided either in the rear or in the front element; if two lenses are used, the case be provided both in the front and rear elements. In the latter case, both lenses move away from one another at accomodation for near sight, and approach one another at accommodation for long-distance sight. In addition thereto, the system may be complemented by provision of one or more further intraocular lenses.

It is important that the accommodation proceeds only by shifting the substitute lens in the eye axis forward and backwards, similarly as in photographic cameras, and not by changing the shape of the lens as it is in a healthy eye, where the shift of the lens in the eye axis is smaller and occurs in parallel with the change in its curvature, i.e. with the change in its optical power. The so-called zoom effect, which takes place in a healthy eye during accomodation to a smaller extent, may be also attained with the system according to this invention with two or more lenses, without parallel change in the optical power of the individual lenses.

In the following, the intraocular optical system according to the invention will be explained with reference to specific embodiments shown in Figures 1 to 6.

Figure 1 shows a section of a first embodiment of the intraocular optical system 7 according to the present invention which consists of a front element 1, a ring-shaped elastically deformable element 3 comprising an equatorial slot provided with holes 9 at the circumference, and a rear element 2 comprising the lens 4. The lens 5 is inserted into the front element 1 of the system 7 the front opening of the front element 1 being somewhat smaller than the diameter of the front lens 5. The whole system 7 is placed in the capsula lentis 6.

Figure 2 shows the same section as in Figure 1, viewed from above across.

A sectional view of another embodiment of the intraocular optical system of this invention is shown in Figure 3, in which the front element 1 comprising the lens 5 and the rear element 2 with integrated lens 4 are connected by means of the elastically deformable element 3 realized as a spring which simultaneously centers the lenses 4, 5 or the front and rear elements 1, 2, respectively.

Figure 4 represents a section through an intraocular optical system 7 of the invention, where the front element 1 and the rear element 2 are shaped as rings connected to the elastically deformable element 3 also forming a ring. The lenses 4 and 5 are inserted into radially inner slots. The whole system is placed in the capsula lentis 6.

The intraocular optical system 7 shown in Figure 5 in a sectional view consists of the front element 1 and the rear element 2 having the shape of a part of an ellipsoid of revolution and the elastically deformable element 3 provided with an equatorial slot comprising a row of holes 9. The lens 5 is inserted into the front element 1 in a manner similar to that of Figure 1.

Figure 6 shows a section of another embodiment of the intraocular system 7 where the lenses 4, 5, the front element 1, the rear element 2 and the elastically deformable element 3 are monolithically integrated and form one single piece. The hole 8 in the central part of the front lens 5 allows the chamber liquor to circulate.

As may be seen from Figure 6, the front and/or back lens or front and/or rear element may be provided with a central opening, and/or the elastically deformable element may comprise an equatorial slot with a row of holes for liquid passage. The elastically deformable element 3 may be or may be complemented with a centrically provided spiral spring or other elastic connection elements, where liquids can flow in between. The lenses 4, 5 may be fixed in the rear element 2 or in the front element 1 of the system 7 or in both parts, or may be held in the eye axis by radial or oblique fibers. The obliqu fibers are longer than the straight

radial fibers and may be therefore easily elastically stretched.

In the most simple arrangement, the system 7 may comprise two ring-shap d elements 1, 2 connected with the elastically d formable element 3, the space therebetween enabling the flow of surrounding liquid. These rings preferably have a diameter of less than 9 mm.

The elastically deformable element 3 may have the form of fibers, strips, a spiral or a corrugated body so that the capsule lentis is moderately and uniformly tensioned by these rings. The elements 1, 2 may also be parts of hollow bodies of revolution, such as a sphere, a paraboloid, an ellipsoid, and the like. They may be made from various biocompatible materials, advantageously of elastic material with shape memory, for example, partially dried hydrogels which may be hydrophilized at the surface, for example, by partial hydrolysis or sulfonation, which may be completed by a partial surface esterification with multifunctional alcohols containing, even after cross-linking esterification, additional free hydrophilic groups, silicone composites, and the like.

It is advantageous to provide an opening in the front element 1 or the front lens 5 of the system 7 which is larger than the hole in the front part of the capsula lentis formed at the extraction of the natural lens. The non-uniform edges of the hole are not mechanically stressed in this way.

The intraocular optical system 7 and/or the lenses 4, 5 may contain a drug in their material, which is released after implantation. Such drugs may be cytostatics or antibodies liquidating cells on the inner wall of the capsula lentis which cause a secondary cataract by producing the lens materials, corticoids, antibiotics, and the like. These drugs disappear after a certain time.

The front lenses 5 of the system 7 may be provided in the center with a hole of a diameter of 0.05 to 1 mm which enables a better communication between the anterior and posterior chambers of the eye and prevents from the formation of a secondary glaucoma. This hole does not affect the optical quality of the image.

The intraocular optical system 7 according to the invention may be manufactured in various ways similar to the manufacture of intraocular lenses, viz. by turning, rotation casting, or dipping.

It is advantageous to produce the system 7 in a way similar to that of the manufacture of intraocular lenses according to CS patent application PV 9596-86, so that its glass-transition temperature T_g is from -5 to 45 °C. A system on that basis may be deformed at a temperature above T_g to a form suitable for implantation and cooled down to fix this deformed shape. After insertion into the capsula lentis 9, the system 7 relaxes by post-swelling and warming up to the temperature of the eye and thus acquires the desired final shape.

Claims

1. Intraocular optical system (7) for insertion into the capsula lentis after removal of the natural eye lens,
characterized in that it

(A) is a hollow body having an outer shape following the inner shape of the capsula lentis (6) at least in the main lines and leaning against the inner wall of the capsula lentis (6) and keeping it in a moderately tensioned state,
and

(B) comprises
- a front element (1),
- a rear element (2),
- an elastically deformable element (3) provided between the front element (1) and the rear element (2),
and
- one to four lenses (4, 5) arranged such as to be placed in the main axis of the eye, at least one of the lenses (4, 5) being provided such as to move axially at contraction and release of the accommodation muscles of the eye and thus to change its position between the retina and the cornea.

2. The intraocular optical system (7) according to claim 1, characterized in that at least one of the lenses (4, 5) is fixed in the axis of the system by the elastically deformable element (3) and/or the front element (1) and/or the rear element (2).

3. The intraocular optical system (7) according to claim 1 or 2, characterized in that the front element (1) and/or the rear element (2) and/or the elastically deformable element (3) are rings or parts of hollow bodies of revolution such as a sphere, a paraboloid, an ellipsoid, and the like.

4. The intraocular optical system (7) according to one of claims 1 to 3, characterized in that one or more of the lenses (4, 5) are connected to or integrated with the front element (1) or the rear element (2) to form one single piece.

5. The intraocular optical system (7) according to one of claims 1 to 4, characterized in that the front element (1) and/or the rear element (2) are connected to or integrated with the elastically deformable element (3).

6. The intraocular optical system (7) according to one of claims 1 to 5, characterized in that the elastically deformable element (3) is provided with openings (9) allowing the flow of liquid.

7. The intraocular optical system (7) according to one of claims 1 to 6, characterized in that the elastically deformable element (3) is provided with a circumferential slot.

8. The intraocular optical system according to one of claims 1 to 7, characterized in that the front element (1) or the front lens (5) and/or the back lens (4) are provided with an opening (8) having a diameter which is smaller than that of the hole in the capsula lentis (6).

9. The intraocular optical system (7) according to one of claims 1 to 8, characterized in that the elastically deformable element (3) has elasticity in directions parallel to the optical or geometrical axis of the system.

10. The intraocular optical system (7) according to one of claims 1 to 9, characterized in that the elastically deformable element (3) has the form of fibers, strips, a spiral or of a corrugated body.

11. The intraocular optical system (7) according to one of claims 1 to 10, characterized in that at least one of the lenses (4, 5) is placed outside the geometrical center of the system and of the capsula lentis (6).

12. The intraocular optical system (7) according to one of claims 1 to 11, characterized in that it consists partially or in its entirety of one or more biocompatible materials, particularly of silicon elastomers, hydrogels, preferably elastic hydrogels having shape memory, partially dried hydrogels hydrophilized at the surface, a material having a glass transition temperature (T_g) of -5 to 45 °C and/or a material the glass transition temperature of which is adjusted in the state before insertion into the eye to a required value, e.g. by swelling a hydrogel into a non-equilibrium state.

13. The intraocular optical system (7) according to claim 12, characterized in that it is present before insertion into the eye in a deformed state of rod-like shape having a diameter < 3 mm.

14. The intraocular optical system (7) according to one of claims 1 to 13, characterized in that at least one of the lenses (4, 5) is made from a synthetic polymer having a refractive index ≥ 1.336.

15. The intraocular optical system (7) according to one of claims 1 to 14, characterized in that it is made partially or in its entirety from a homopolymer or a copolymer on the basis of acrylates, methacrylates and/or hydroxyethyl methacrylate.

16. The intraocular optical system (7) according to one of claims 1 to 15, characterized in that one or all of the lenses (4, 5) are provided with a center hole having a diameter of 0.05 to 1 mm.

17. Th intraocular optical system (7) according to one of claims 1 to 16, characterized in that it contains drugs which are released into the eye after implantation.

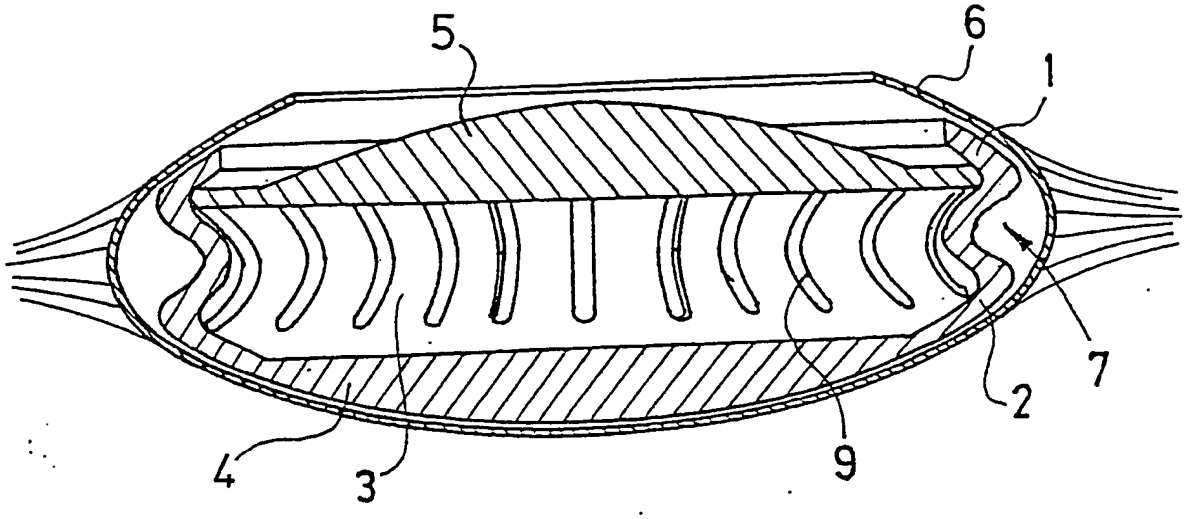

FIG.1

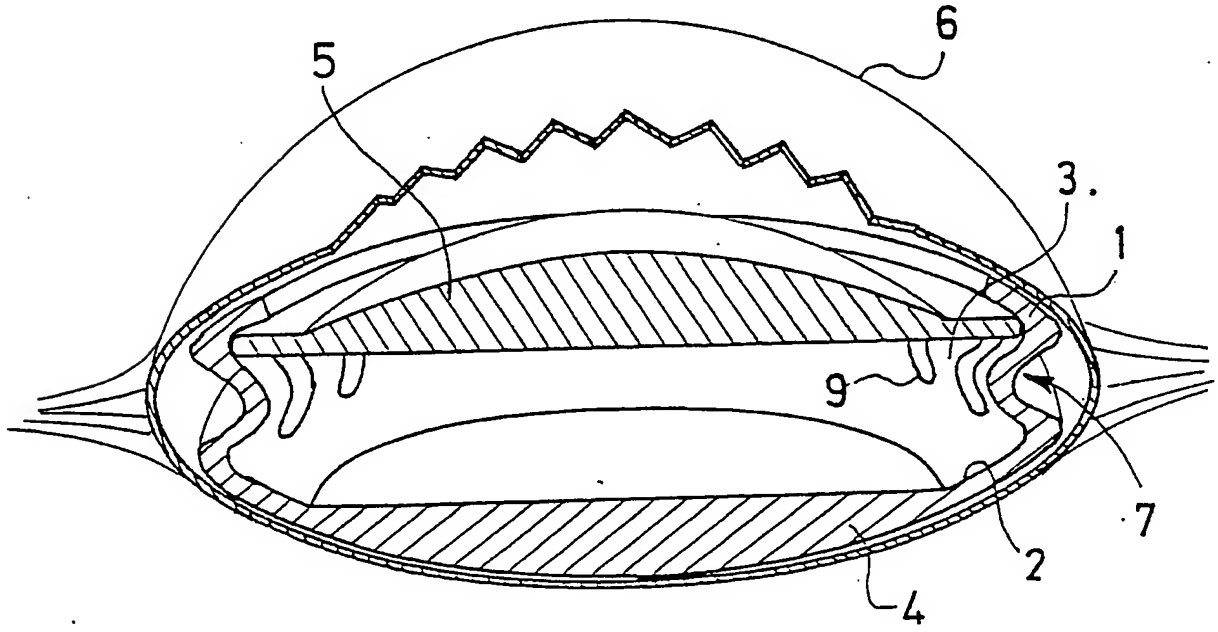

FIG. 2

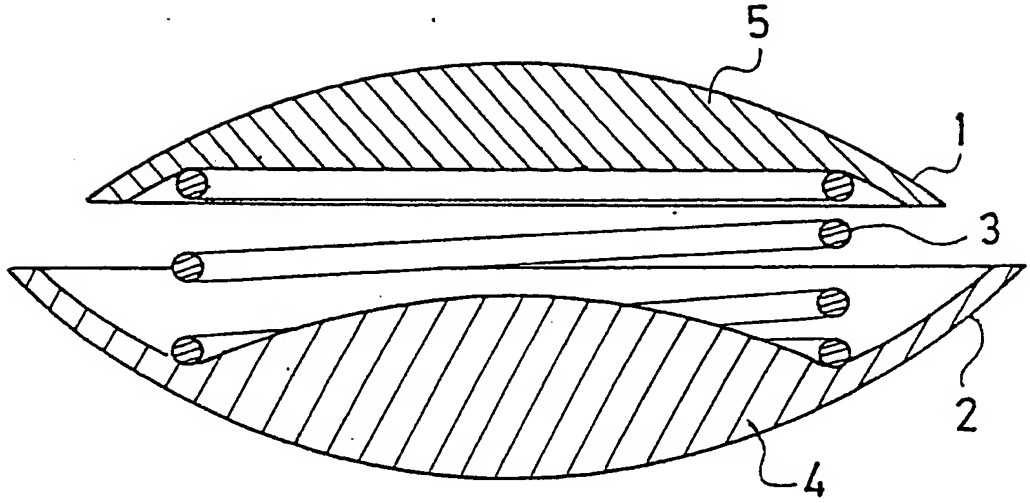

FIG. 3

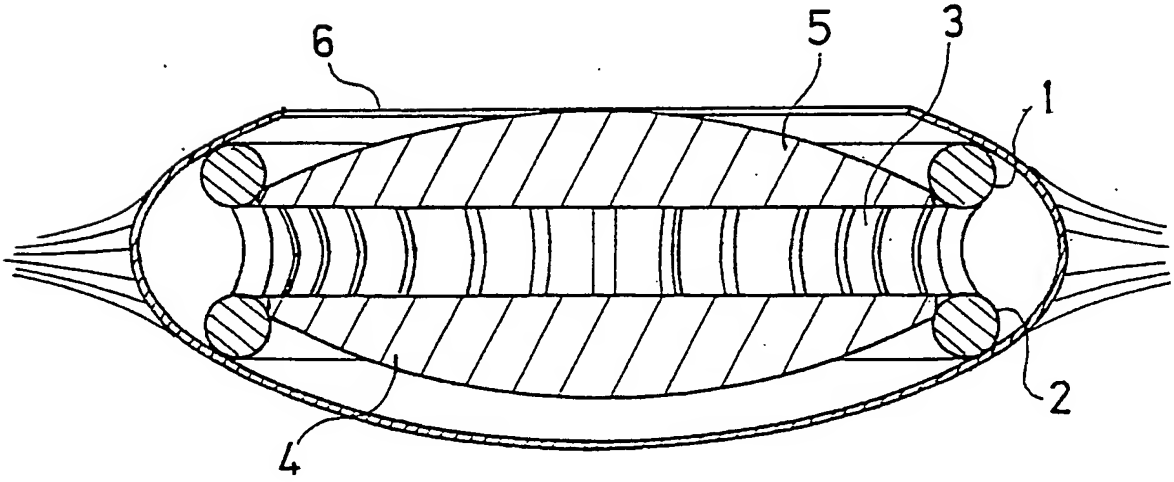

FIG. 4

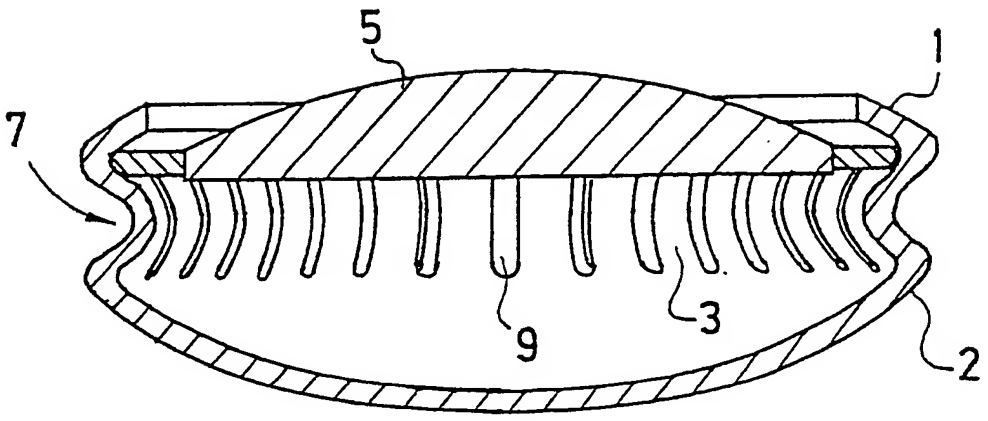

FIG.5

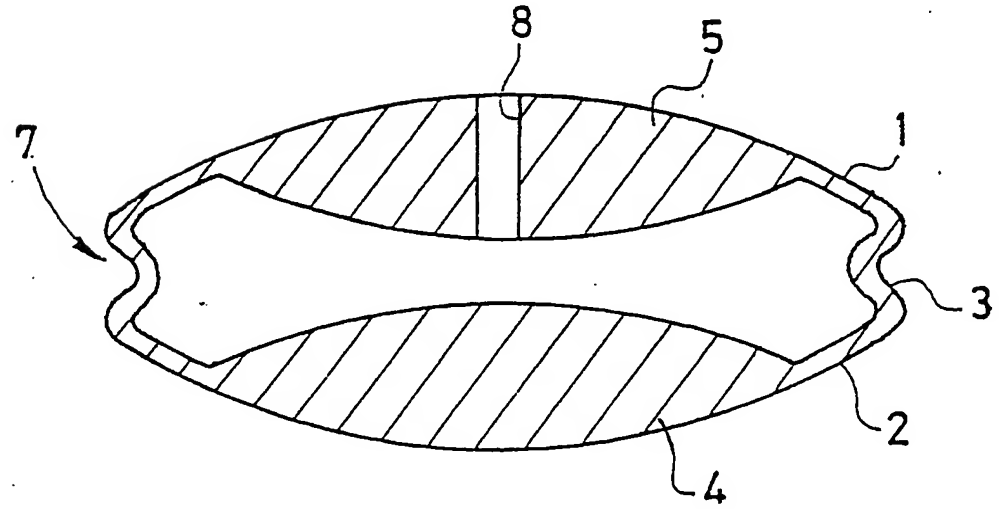

FIG.6